A NEW SPECIES OF *BINODOXYS* (HYMENOPTERA: BRACONIDAE: APHIDIINAE), PARASITOID OF THE SOYBEAN APHID, *APHIS GLYCINES* MATSUMURA, WITH COMMENTS ON BIOCONTROL

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Abstract.—***Binodoxys kelloggensis*** **Pike, Starý, and Brewer, n. sp.** (Hymenoptera: Braconidae: Aphidiinae), is described and illustrated. This aphidiine parasitoid, found in southcentral Michigan, is considered a native species, reared from the exotic soybean aphid, *Aphis glycines* Matsumura, from naturally infested field soybeans and from aphid-infested potted soybeans placed outdoors among assorted plants. It is one of eight parasitoid species now known to attack *A. glycines* in North America.

Key Words: parasitoid, aphidiine, *Binodoxys*, aphid, *Aphis*, soybean, new species, description

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A main listing of the aphidiine parasitoids in North America is provided in the Catalog of Hymenoptera in America North of Mexico (Marsh 1979). Research undertaken in the Pacific Northwest (Pike et al. 2000) supplemented this list substantially both in taxonomy and aphid host range information on the group. However, for much of North America, the faunal composition, host range, and ecology of the aphidiines have not been extensively explored. There is a lack of information on the adaptation of local parasitoids to newly introduced pest aphid species, and insufficient or misleading information on the adaptation of accidentally or purposely introduced exotic parasitoids to both native and exotic host aphids.

The new soybean aphid pest, *Aphis glycines* Matsumura (Heimpel and Shelly 2004, Ragsdale et al. 2004, Venette and Ragsdale 2004), which is rapidly expanding its range, affords an opportunity to examine the adaption of local and introduced parasitoids to the new invasive aphid, and to document the unfolding events much the same as was undertaken in North America for the Russian wheat aphid, *Diuraphis noxia* (Kurdjumov) (Pike et al. 2000, Noma et al. 2005).

From field studies on soybean aphids in southcentral Michigan, a native, undescribed species of *Binodoxys* Mackauer was discovered attacking the aphid. The new parasitoid species is herewith named and described. Also provided is a complete listing of all parasitoids, both native and introduced, that to date have been documented to use soybean aphid as a host in North America.

The new parasitoid reared from *A. glycines* was taken from (1) naturally infested soybean field plots at the Michigan State University–Entomology Farm (EF) at East Lansing, Michigan, and (2) naturally infested soybean field plots and artificially infested potted soybeans placed for a time in field plots of assorted plants at the Michigan State University–Kellogg Biological Station, Long-Term Ecological Research plots (KBS) near Hickory Corners, Michigan. Field exposures of potted soybeans at KBS were in or near blocks of alfalfa, corn, clover, poplar, soybean, wheat, and mixed stands of clover, dogbane, goldenrod, Queen Ann's lace, sumac, and timothy. Collections were made by T. Noma, S. Langley, and M. Kaiser, unless otherwise indicated.

Parasitoids of *Aphis glycines* in Michigan

Aphelinidae

Aphelinus albipodus (Hayat and Fatima)

Material.—USA, Michigan, EF, 19-Sep-2003; KBS, 1-Aug-2003, 16-Jul & 16-Aug-2004. T. Noma collector.

Aphelinus asychis (Walker)

Material.—USA, Michigan, EF, 8-Aug-2003; 23-Aug & 13-Sep-2004; KBS, 1-Aug-2003; 16-Jul, 16-Aug & 7-Sep-2004. T. Noma collector.

Braconidae: Aphidiinae

Aphidius colemani Viereck

Material.—USA, Michigan, EF, 9-Jul-2003, 23-Aug-2004; KBS, 27-Jun, 1-Aug, & 12-Sep-2003, 7-Sep-2004. T. Noma collector.

Aphidius ervi Haliday

Material.—USA, Michigan, KBS, 16-Aug & 7-Sep-2004. T. Noma collector.

Binodoxys kelloggensis **Pike, Starý, and Brewer, new species**

(Figs. 1–8)

Material.—Holotype ♀ (whole mount, dry): USA, Michigan, Kalamazoo Co., near Hickory Corners, Michigan State University–Kellogg Biological Station, Long-Term Ecological Research Plots (N 42.4, W 85.4), 8-Sep-2004, A. Costamagna collector. Reared from *Aphis glycines* Matsmura derived from a naturally-infested field plot of soybeans (*Glycine max*). In the vicinity were 1-hectare blocks of alfalfa, clover, corn, poplar, wheat, and mixed stands of clover, dogbane, goldenrod, Queen ann's lace, sumac, and timothy. Holotype deposited in the National Museum of Natural Hisrtory, Smithsonian Institution, Washington, DC (USNM).

Paratypes: 62 specimens, all from the Kellogg Biological Station, reared from *A. glycines* in August or September 2004. Nine (4 ♀, 5 ♂) were from the same rearings as the holotype, the remainder were derived from *A. glycines* introduced and allowed to multiply on potted soybeans placed outdoors in stands of alfalfa, poplar, and mixed stands of clover, dogbane, goldenrod, Queen Ann's lace, sumac, and timothy. Paratypes deposited in part in collections of USNM (8 ♀, 8 ♂), Michigan State University, East Lansing (8 ♀, 8 ♂), Washington State University, Prosser (12 ♀, 4 ♂), and P. Starý, Czech Republic (9 ♀, 5 ♂).

Diagnosis.—*Binodoxys kelloggensis* is characterized by 11-segmented antenna, by characters on the petiole where the primary (= spiracular) and the secondary tubercles are almost of equal size and their mutual distance of separation is distinctly shorter than the width across the primary tubercles. The prongs bear 2 long setae on the upper side and 6–9 long setae on the lower side; upper and lower marginal setae are of similar length; with

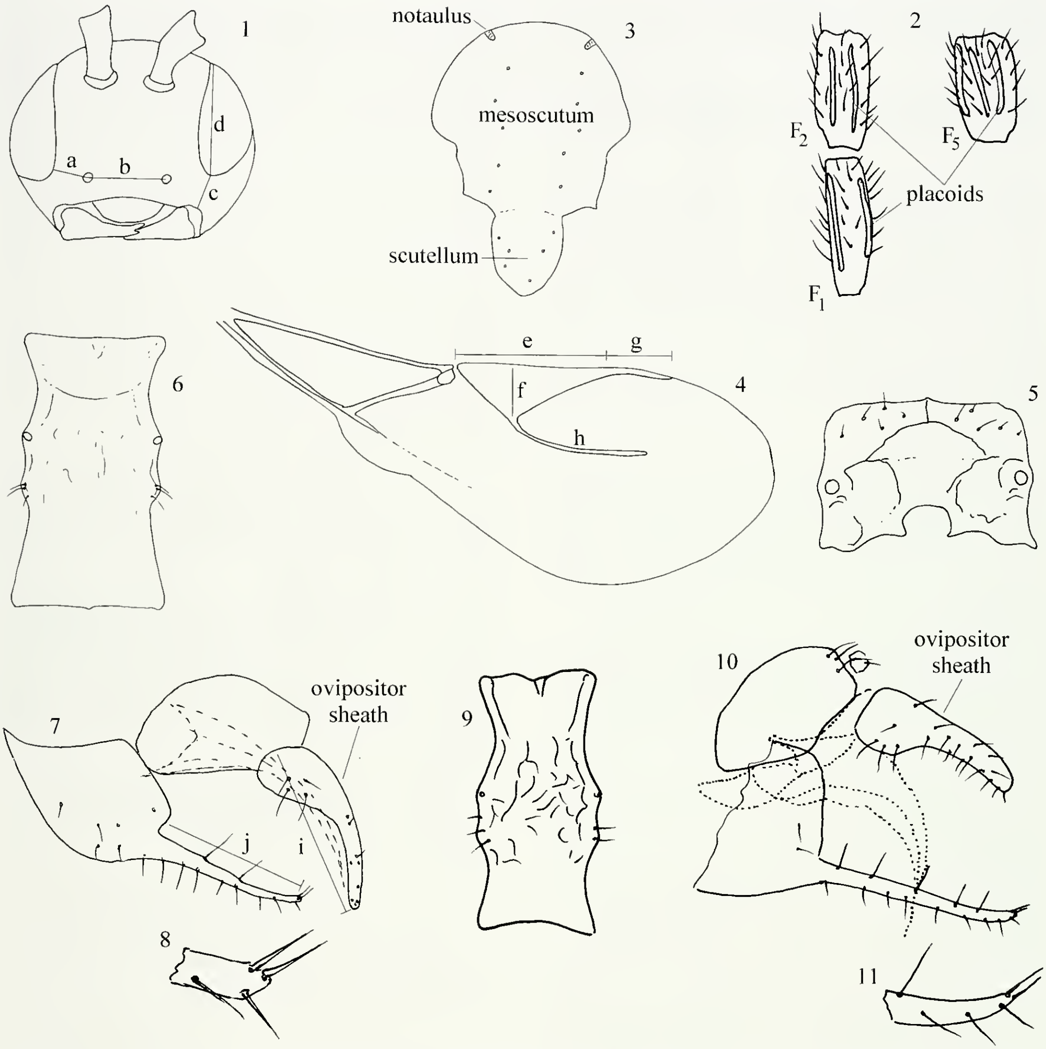

Fig. 1–11. Various morphological features (illustrations not to same scale). 1–8, *Binodoxys kelloggensis*. 1, Head (a, tentorio-ocular distance; b, inter-tentorial distance; c, malar space; d, length of eye). 2, Antennal flagellomeres. 3, Mesonotum (setal number and arrangement shown on mesoscutum [medial-pleural region] and scutellum). 4, Forewing (e, length of stigma; f, width of stigma; g, R1 post-marginal vein (= metacarpus); h, RS vein (radial sector). 5, Propodeum. 6, Petiole. 7, Genitalia (i, length of ovipositor sheath; j, length of prong). 8, Prong apex (close-up). 9–11, *B. carolinensis*. 9, Petiole. 10, Genitalia. 11, Prong apex (close-up).

2 long simple apical setae on the upper side. It is described from *Aphis glycines* from Michigan.

Of the local native species, *B. carolinensis* (Smith 1944), described from *Aphis* sp. in North Carolina (Smith 1944), seems to be the closest relative, characterized as follows: Antenna 11-segmented. The prongs bear 5 long setae on the upper side and 9 setae on the lower side which are about half the length of the opposite upper setae; with 2 long setae at the apex. Also, there are some differences in characters of the petiole and ovipositor between the two species (Figs. 6–7, *B. kelloggensis*—petiole and genitalia; Figs. 9–10 [illustrated by Starý from a slide mounted paratype], *B. carolinensis*—petiole and genitalia).

Certain exotic East Asian *Binodoxys* spp. (Starý et al. unpublished data), if established in North America as control agents of *A. glycines*, might also cause identification problems. Though the East Asian spp. are very similar to *B. kelloggensis*, they are distinguishable by characters on the prongs which bear 4–5 long setae on the upper side, with the upper setae being longer than the lower opposite setae; also, characters on the petiole are different.

Etymology.—The name of the new species is derived from the type location, the Kellogg Biological Station near Hickory Corners, Michigan. The name is attributed to K. Pike, P. Starý and M. Brewer.

Description.—Female. *Head* (Fig. 1): Eyes medium-sized. Malar space equal to 1/4 of eye length. Antenna 11-segmented. Flagellar segment 1 (= F1) (Fig. 2, Table 1) usually slightly >2.5 as long as wide, usually with 2 or 3 placodes, setae semi-erect and equal to 1/3 of segment. F2 (Fig. 2) about 0.8–0.9× F1, approximately twice as long as broad, about 1/5 thicker than F1, with 4–5 placodes. F5 (Fig. 2) slightly wider than F2. *Mesosoma* (Fig. 3): Mesoscutum with notauli distinct in ascendent portion, effaced on disc where traced by a few long setae. Propodeum (Fig. 5) with a broad pentagonal areola, carinae distinct, with a few setae. *Forewing* (Fig. 4, Table 1): Stigma triangular, slightly <3 times as long as broad, R1 (= metacarpus) shorter than stigma length by a factor of 0.4–0.7. RS three times as long as stigma width; lower marginal setae distinctly longer than surface setae. *Metasoma*: Petiole (Fig. 6) about twice as long as width across primary tubercles; distance between primary (= spiracular) and secondary tubercles less than half width across primary tubercles; width across primary tubercles very slightly (about 1/20) shorter than across secondary tubercles; feebly rugose with a short longitudinal carina in second third; with sparse long setae near secondary tubercles. *Genitalia* (Figs. 7–8): Ovipositor sheaths remarkably narrow in distal portion and curved [compare *B. kelloggensis* (Fig. 7) with *B. carolinensis* (Fig. 10)]. Prongs relatively short and strong, slightly arcuate at apex; with 2 long setae on upper side; with 2 long simple setae at apex; with 6–9 long setae on lower side; length of upper side and lower side setae about equal.

Color: Head dark brown, palpi brown. Antenna brown, scape, pedicel and narrow base of F1 light brown. Mesosoma dark brown. Wing venation brown. Legs brown, narrow basal portion of tibiae light brown. Metasoma generally brown. Petiole light brown. Basal spot at tergum 2 light brown. Ovipositor sheaths and prongs dark brown.

Length of body: ca. 1.2 mm.

Male. Antenna 12–13 segmented. Coloration similar to female.

Diaeretiella rapae (M'Intosh)

Material.—USA, Michigan, EF, 17-Jun-2003. T. Noma collector.

Lysiphlebus testaceipes (Cresson)

Material.—USA, Michigan, EF, 8-Aug & 19-Sep-2003, 21-Jun, 23-Aug & 13-Sep-2004; KBS, 27-Jun, 1-Aug & 12-Sep-2003, 16-Aug and 7-Sep-2004. T. Noma collector.

Praon sp.

Material.—USA, Michigan, EF, 21-Jun-2004; KBS, 12-Sep-2003. T. Noma collector.

Discussion

Research on the adaptation of local parasitoids is usually realized within the

Table 1. Feature measurements (μm), counts, and comparison of female and male *Binodoxys kelloggensis* (from paratype series, n = 21 females, n = 14 males).

Features	Female Avg. (range)	Male Avg. (range)
Head		
Antenna flagellomeres		
F1 (length)	92 (73–110)	88 (75–100)
F2 (length)	78 (68–90)	81 (70–90)
F5 (length)	83 (70–100)	85 (78–100)
F1 (width)	33 (28–43)	34 (28–40)
F2 (width)	35 (30–40)	36 (33–40)
F5 (width)	40 (33–45)	45 (38–50)
Antennal placoids		
F1 (no.)	2.9 (2.0–4.0)	4.1 (2.0–5.0)
F2 (no)	3.9 (3.0–5.0)	4.1 (3.0–5.0)
F5 (no.)	4.8 (4.0–5.0)	4.6 (4.0–5.0)
Eye (length)	146 (135–160)	143 (128–160)
Malar space (length)	36 (35–40)	36 (35–40)
Inter-tentorial distance	101 (95–108)	105 (93–113)
Tentorio-ocular distance	41 (35–45)	38 (25–48)
Wing		
Stigma (length)	286 (250–310)	295 (265–315)
Stigma (width)	103 (90–110)	101 (90–110)
Postmarginal vein (R1)	168 (130–200)	172 (150–200)
Mesoscutal pleural setae	10.9 (8.0–14.0)	8.8 (6.0–11.0)
Propodeal setae, anterior area	10.6 (8.0–14.0)	10.5 (9.0–12.0)
Petiole		
length	184 (150–200)	180 (170–188)
width at spiracular tubercles (1°)	94 (80–105)	88 (83–90)
width at secondary tubercles (2°)	87 (75–103)	83 (83–95)
distance betw 1° and 2° tubercles	34 (20–45)	30 (20–40)
Genitalia		
Ovipositor sheath (length)	150 (140–155)	
Prong (length)	143 (115–155)	
Prong lowerside setae (no.)	2.1 (2.0–2.5)	
Prong upperside setae (no.)	7.6 (6.0–9.0)	
Comparisons		
Malar space / eye	0.24 (0.22–0.26)	0.25 (0.22–0.27)
F1 (length / width)	2.75 (2.35–3.18)	2.55 (2.14–3.27)
F2 (length / width)	2.24 (1.69–2.57)	2.23 (2.06–2.46)
F5 (length / width)	2.10 (2.00–2.38)	1.90 (1.70–2.13)
F5 / F2	0.96 (0.94–1.12)	1.06 (1.00–1.11)
Petiole (length / width at 1° tubercle)	1.96 (1.84–2.25)	2.00 (1.90–2.13)
2° / 1° tubercle	0.93 (0.86–1.08)	0.94 (0.91–0.97)
Stigma (length/width)	2.79 (2.48–3.00)	2.91 (2.65–3.33)
Stigma / R1	1.71 (1.35–2.31)	1.71 (1.50–2.07)

framework of post-introduction studies on a target pest aphid. Pike et al. (2000) published extensive information on Northwest USA local parasitoid fauna and tri-trophic associations (plant-aphid-parasitoid), including adaptations of local parasitoids to exotic invasive aphids (e.g., *Diuraphis noxia* and *Brachycorynella asparagi*), and exotic established parasitoids to local and exotic aphids. Noma et al. (2005) found in post-introduction parasitoid studies on *D. noxia* in the northcentral Great Plains that the majority of the parasitoids adapting to and utilizing the invasive aphid were local species.

Aphis glycines, as a new invasive aphid pest in North America, tends to reflect the case of *D. noxia* on small grains – inadvertent pest introduction, subsequent pest expansion, adaptation of local parasitoids combined with foreign searches, importation, and establishment of new exotic parasitoid species.

The presented determinations, eight parasitoids in total, are some of the first records of parasitization of *A. glycines* by local or exotic established parasitoid species in North America (see also Nielsen and Hajek 2005). *Aphelinus albipodus* and *Aphidius colemani* are examples of exotic species. *Aphidius colemani* was introduced against Russian wheat aphid and other aphids in North America and *A. albipodus* against Russian wheat aphid. Both are now established in several states. In addition to the original target pest aphids, they have been found to utilize some alternate aphids, including *A. glycines*. The appearance of *A. colemani* on *A. glycines* as a biocontrol agent was somewhat predictable (see Lin and Ives 2003). *Binodoxys kelloggensis* is apparently a native species which has secondarily adapted to the newly introduced soybean aphid. Its true native aphid hosts have not been determined, but probably they are in the genus *Aphis*. At the type locality, where a mix of plants exists, six local aphid species have been found [*Acyrthosiphon pisum* (Harris), *Aphis* sp., *Nearctaphis bakeri* (Cowen), *Rhopalosiphum padi* (L.), *Therioaphis trifolii* (Monell) and *Uroleucon caligatum* (Richards)], but none of these are directly linked with the parasitoid to date.

A number of other local aphidiines parasitize various *Aphis* spp. and related groups, and we expect in time that some of these will adapt to the congeneric *A. glycines*. North America is rich in species (see Pike et al. 2000) that utilize members of the genus *Aphis*. In general, the aphidine aphids are associated with the highest number of parasitoid species among the subfamilies of aphids (Starý and Rejmanek 1981, Potter and Hawkins 1998). The adaptation of local parasitoids is also in agreement with the Rule of Faunistic Complexes in the biological control of aphids (Starý 1968, 1970).

The value of *A. albipodus* and *A. colemani* as introduced exotics has increased with their parasitization of two exotic aphid pests (*D. noxia*, *A. glycines*). A similar situation has developed with *A. ervi* in Chile (Starý 1996), and with *L. testaceipes* in the Mediterranean region of France (Starý et al. 1988), Portugal (Cecilio 1994) and Spain (Michelena et al. 1994). Such multilateral biocontrol results in added economic savings which unfortunately have not been evaluated.

Aphis glycines, as an exotic, expanding pest in North America, is to some extent a useful model to demonstrate and verify parasitoid dynamics relative to multiple target and nontarget hosts, and their adapation to differing environments across areas of aphid expansion.

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